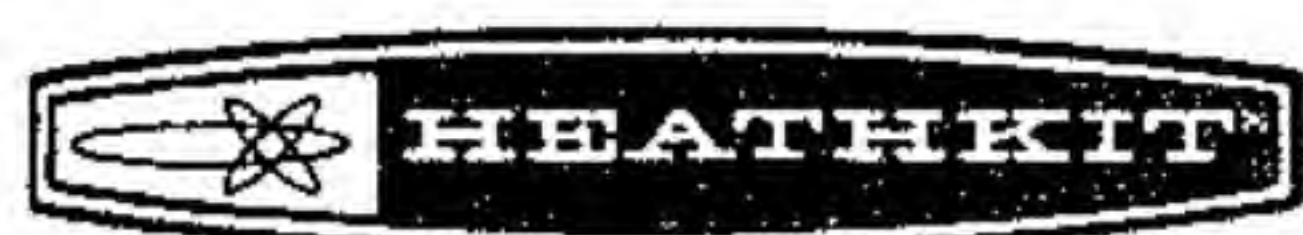
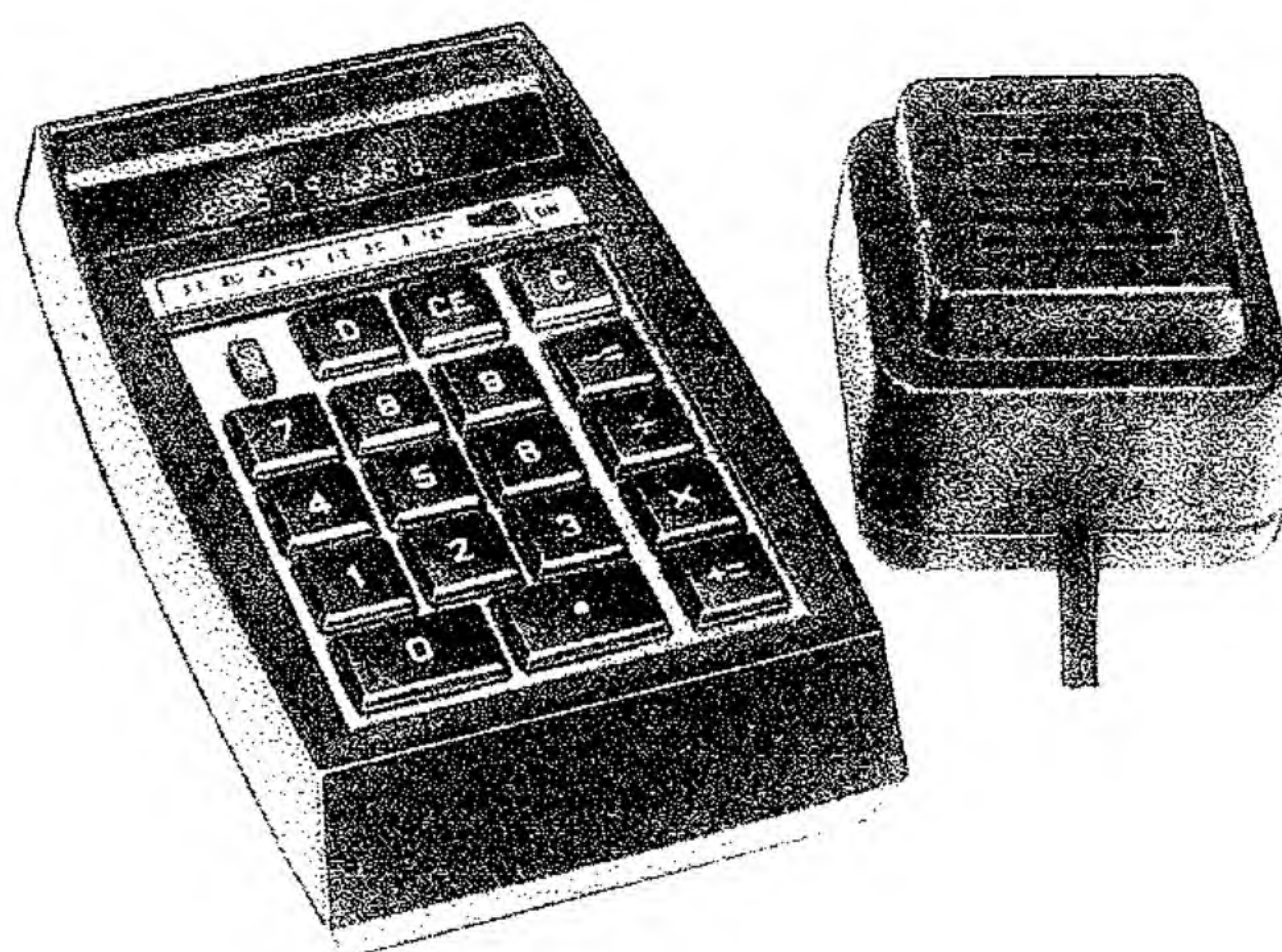


Assembly
of the



PORTABLE ELECTRONIC CALCULATOR

MODEL IC-2009



HEATH COMPANY
BENTON HARBOR, MICHIGAN 49022

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INTRODUCTION

The Heathkit Model IC-2009 Portable Electronic Calculator adds, subtracts, multiplies, and divides with speed, accuracy, and convenience. Several features of the Calculator are: A large-scale integrated circuit, rechargeable nickel-cadmium battery, and an 8-digit, easy-to-read display.

A sophisticated integrated circuit (IC) is the heart of the all-solid-state circuit. This MOS/LSI* device performs all of the mathematical operations of the Calculator.

A constant number (K) can be entered into the Calculator to speed up repetitive calculations in multiplication and division. By sequencing the basic functions of the Calculator and using a constant, you can quickly complete complex mathematical calculations that would otherwise be very lengthy and tedious operations.

Operation as a portable unit is extended by a special "battery saver" circuit which turns off the display 15 seconds after the last digit or function entry. In this mode, up to eight hours of use are available and approximately five hours for the busiest figuring. After the display has automatically turned off, the last display can be recalled by simply pressing the display recall (D) key. Display recall will also occur upon the entry of another number or function.

A low battery condition is indicated by a special (L) display, warning you that it is time to charge the battery. There is, however, sufficient charge remaining which will allow approximately fifteen minutes of valid calculations. Battery charging is accomplished by plugging the Calculator into the Charger (furnished with the kit) that operates from a standard wall outlet. Continuous desk-top operation is obtained by keeping the Calculator connected to the Charger.

The attractive, modern styling and small size of the Calculator make it ideally suited for use anywhere. The Calculator and Charger are housed in high-impact-strength, plastic cabinets with a nonslip textured surface. The display is sloped for easy, wide-angle viewing.

Accessibility to all parts by the use of plug-in keyboard and display board make the Calculator easy to maintain. Whether you use the Calculator in business or for personal applications, you will find it to be a useful tool in your everyday calculations.

Refer to the "Kit Builders Guide" for complete information on unpacking, parts identification, tools, wiring, soldering, and step-by-step procedures.

*MOS (Metal Oxide Semiconductor)/LSI (Large Scale Integration).

PARTS LIST

Check each part against the following list. The key numbers correspond to the numbers in the Parts Pictorial (fold-out from Page 9). Any part that is packed in an individual envelope with the part number on it should be placed back in the envelope after it is identified until it is called for in a step.

To order replacement parts: Use the Parts Order Form furnished with this kit. If one is not available, see "Replacement Parts" in the "Kit Builders Guide."

KEY PART No.	KEY PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
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RESISTORS

NOTE: The following resistor tolerances are 5% unless otherwise noted. 5% is indicated by a fourth color band of gold, while 10% is indicated by a fourth color band of silver.

1/4-Watt

A1	1-58-12	1	47 Ω (yellow-violet-black)	.10
A1	1-103-12	10	150 Ω (brown-green-brown)	.10

KEY PART No.	KEY PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
1/4-Watt (cont'd.)				
A1	1-118-12	2	620 Ω (blue-red-brown)	.10
A1	1-68-12	1	820 Ω (gray-red-brown)	.10
A1	1-97-12	5	2400 Ω (red-yellow-red)	.10
A1	1-76-12	8	4700 Ω (yellow-violet-red)	.10
A1	1-14-12	3	12 k Ω , 10% (brown-red-orange)	.10
A1	1-91-12	2	22 k Ω (red-red-orange)	.10
A1	1-86-12	1	470 k Ω (yellow-violet-yellow)	.10

CAPACITORS

B1	20-183	2	120 pF mica	.25
B2	21-140	1	.001 μ F disc	.10
B2	21-95	2	.1 μ F disc	.15
B3	25-281	3	39 μ F tantalum	.45

KEY PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
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CODES

56-56	6	1N4149	.20
56-602	2	Germanium	.25
57-65	1	1N4002	.20

NOTE: Transistors and integrated circuits are marked for identification in one of the following four ways:

1. Part number.
2. Type number. (On integrated circuits this refers only to the numbers; the letters may be different or missing.)
3. Part number and type number.
4. Part number with a type number other than the one listed.

TRANSISTORS

417-168	4	TIS37	.45
417-808	4	2N3702	.35
417-809	5	2N3704	.35

INTEGRATED CIRCUITS

CAUTION: The large integrated circuit (#443-618) can be damaged by static electricity. Do not remove it from its package until you are instructed to do so step.

443-618	1	TMS0103	23.30
443-619	2	SN75491	2.25
443-620	2	SN75492	2.25

KEY PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
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HARDWARE

#2 Hardware

F1	250-582	2	#2 x 1/4" screw	.05
F2	250-1172	2	2-56 x 1/4" screw	.05
F3	250-1112	2	2-56 x 3/4" screw	.05
F4	252-51	2	2-56 nut	.05
F5	253-126	2	#2 flat fiber washer	.05
F6	254-26	2	#2 lockwasher	.05

#4 Hardware

G1	250-52	4	4-40 x 1/4" screw	.05
G2	250-477	4	#4 x 3/4" screw	.05
G3	250-1171	2	#4 x 1-1/8" screw	.05
G4	253-43	4	#4 flat fiber washer (black)	.05
G5	255-182	4	Tapped spacer	.05

WIRE

89-49	1	Line cord	.45
134-848	1	Charger cord	.55
340-11	1	Bare wire (used only for soldering iron tip)	.05/ft
344-125	1	Black wire	.05/ft
344-127	1	Red wire	.05/ft
344-134	1	White wire	.05/ft

KEY PART No.	KEY PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
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PLASTIC PARTS

H1	92-82	1	Calculator top	.55
H2	92-83	1	Calculator bottom	.75
H3	92-84	1	Charger top	.35
H4	92-85	1	Charger bottom	
H5	204-1929	2	Circuit board bracket	.10

INSULATORS

J1	75-192	1	Switch insulator	.10
	346-6	1	Sleeving	.05
	382-75	1	Foam pad	.10
	74-6	1	Roll tape	.25
	75-108	1	Insulator sheet (1-3/4" x 2")	.10

CONNECTORS

K1	432-134	34	Connector socket (2 extra)	.10
K2	432-770	51	Connector pin (2 extra)	.10
K3	432-771	1	2-pin connector plug	.10
K4	432-797	2	Fuse connector	.10

KEY PART No.	KEY PART No.	PARTS Per Kit	DESCRIPTION	PRICE Each
-----------------	-----------------	------------------	-------------	---------------

MISCELLANEOUS

L1	54-828	1	Power transformer	3.50
L2	60-79	1	Slide switch	.50
L3	64-614	1	Keyboard	10.90
	85-1285	1	Main circuit board	4.05
	85-1318	1	Display circuit board	.90
	100-1616	1	Set of selected parts consisting of the following:	.60
A1		1	Selected 3000 Ω , 1/4-watt (orange-black-red) resistor	
A1		1	Selected 1/4-watt resistor	
C1		1	Selected diode	
L4	260-53	4	Alligator clip	.10
L5	261-1	8	Rubber foot	.05
L6	411-292	1	Light emitting diode (LED) display	25.50
	418-30	1	Battery	10.50

(DO NOT REMOVE THE TAPE OR INSULATION FROM THE ENDS OF THE BATTERY LEADS, AS THE BATTERY WILL BE DAMAGED IF THE BARED LEADS TOUCH TOGETHER.)



KEY PART No.	Part No.	PARTS Per Kit	DESCRIPTION	PRICE Each
Miscellaneous (cont'd.)				
L7	421-48	1	Thermal fuse	.45
L8	446-611	1	Window	.30
	390-1007	1	Label set	.30
	390-1008	1	Trim label	.25
	391-34	1	Blue and white label	
	597-260	1	Parts Order Form	
	597-308	1	Kit Builders Guide	
		1	Assembly Manual (See front cover for part number.)	2.00
		1	Operation Manual (See front cover for part number.)	2.00
			Solder (Additional 3' rolls of solder, #331-6, can be ordered for 15 cents each.)	

The prices apply only on purchases from the Heath Company where shipment is to a U.S.A. destination. Add 10% (minimum 25 cents) to the price when ordering from a Heathkit Electronic Center to cover local sales tax, postage, and handling. Outside the U.S.A. parts and service are available from your local Heathkit source and will reflect additional transportation, taxes, duties, and rates of exchange.

SPECIFICATIONS

DISPLAY

Readout	8-digit; 7-segment; single plane light emitting diode (LED).
Input Overflow	(E) indicates entry has exceeded 8-digits.
Output Overflow	(O) indicates result has exceeded 8-digits.
Low Battery	(L) indicates battery needs to be charged.

KEYBOARD

Eighteen Keys	10 number keys (0-9). 1 decimal key (.). 4 function keys $+=$, $-=$, \times , \div . 1 clear key (C). 1 clear entry key (CE). 1 display recall key (D).
One Slide Switch	1 constant switch (K).

CAPABILITIES

Functions	Addition. Subtraction. Multiplication. Division.
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Computation Modes	Chain or constant.
Range	10^{-7} to 10^8 (0.0000001 to 99999999.).
Decimal Point	Full floating, entry and result.
Locked Entry	When result exceeds 8-digit capacity.
Factor	Constant (K).
Clear Entry	(CE).
Clear Operation	(C).

GENERAL

Battery Saver	Blanks display except for center segment of center digit (—) for approximately 15 seconds after last number or function entry. Previous display may be recalled with "D" (display) key. Display will light by entering a number or function.
Operation	Portable (from internal battery). Calculator can also be operated while charging.
Operating Temperature	0 to 50 degrees C. (32 to 120 degrees F.)
Charger Input Voltage	120/240 volts AC, 50/60 Hz.

Charger Power Requirements	3 watts.
Operating Time	5 hours typical, depending on display and amount of use when starting with a fully charged battery.
Charge Time	14 hours with Calculator off.
Dimensions	Calculator, 5-1/2" long x 3-1/4" wide x 1-3/4" high. Charger, 2-1/2" long x 1-7/8" high x 2-1/4" wide.
Calculator Weight	12 ounces.
Charger Weight	10 ounces.

The Heath Company reserves the right to discontinue instruments and to change specifications at any time without incurring any obligation to incorporate new features in instruments previously sold.

CIRCUIT DESCRIPTION

Mathematical calculations are made possible through the use of many interrelated circuits that are programmed to act in a timed sequence. This "Circuit Description" will give you a better understanding of the circuit relationships within your Calculator and describe how they work together. Refer to the individual Figures as they are called for, and to the Schematic Diagram (fold-out from Page 75), while you read this information.

IC1

IC1 (Integrated Circuit 1) is the heart of your Calculator. This single "package" contains all the circuits that perform addition, subtraction, multiplication, and division. IC1 can perform these functions either individually or in a chain or constant mode.

Transistors Q1 through Q3 form an oscillator circuit (to be explained later) that provides a signal to the Φ ("clock") input of IC1. This signal causes the internal circuits of IC1 to repeatedly scan the inputs and to pulse the outputs in rapid sequence; this sequence is repeated over and over. This scanning principle, known as multiplexing, is a form of "time sharing" that allows some of the outputs of IC1 to be used for both keyboard inputs and display outputs.

IC1 is also internally programmed to provide protection against key double-entry and transient noise signals. Each time a key is pressed, the IC samples the key switch entry. The same entry is sampled 2.5 milliseconds later to determine its validity. If the entry is proven valid, the IC either memorizes and transfers that particular entry to the driving circuits that light the display, or performs the desired operation.

Automatic locking circuits, within the IC, prevent entry of more than eight digits into the Calculator while signaling more than eight digit entry with an "entry overflow" indication "E" in the extreme left-hand display position. These circuits also prevent further entry once the eight digit output capability has been reached. This condition is indicated by an "output overflow" signal "□" in the extreme left-hand display position.

KEYBOARD

Mathematical commands and numbers are entered into the Calculator through the individual keys of the keyboard. Each keyboard switch is connected between an input and output line of IC1. See Figure 4-1. Pressing the keys provide IC1 with the necessary information to perform the mathematics of the particular problem entered.

As each output (D1 through D11) of IC1 is sequentially pulsed, the internal logic circuitry "keeps track" of which output is being pulsed. When the number 5 key (as an example) is pushed, the pulse signal is coupled from D5 through the keyboard to the KN (number) input of IC1. This is internally registered as a number 5. Using the same output (D5), but instead push the "+=" key, this pulse would be coupled through the keyboard to the KO (operation) input of IC1. This would then be registered as a command to add, or total. Since both of these keys (5 and +=) would not normally be pushed at the same time, there is no confusion as to what operation is desired.

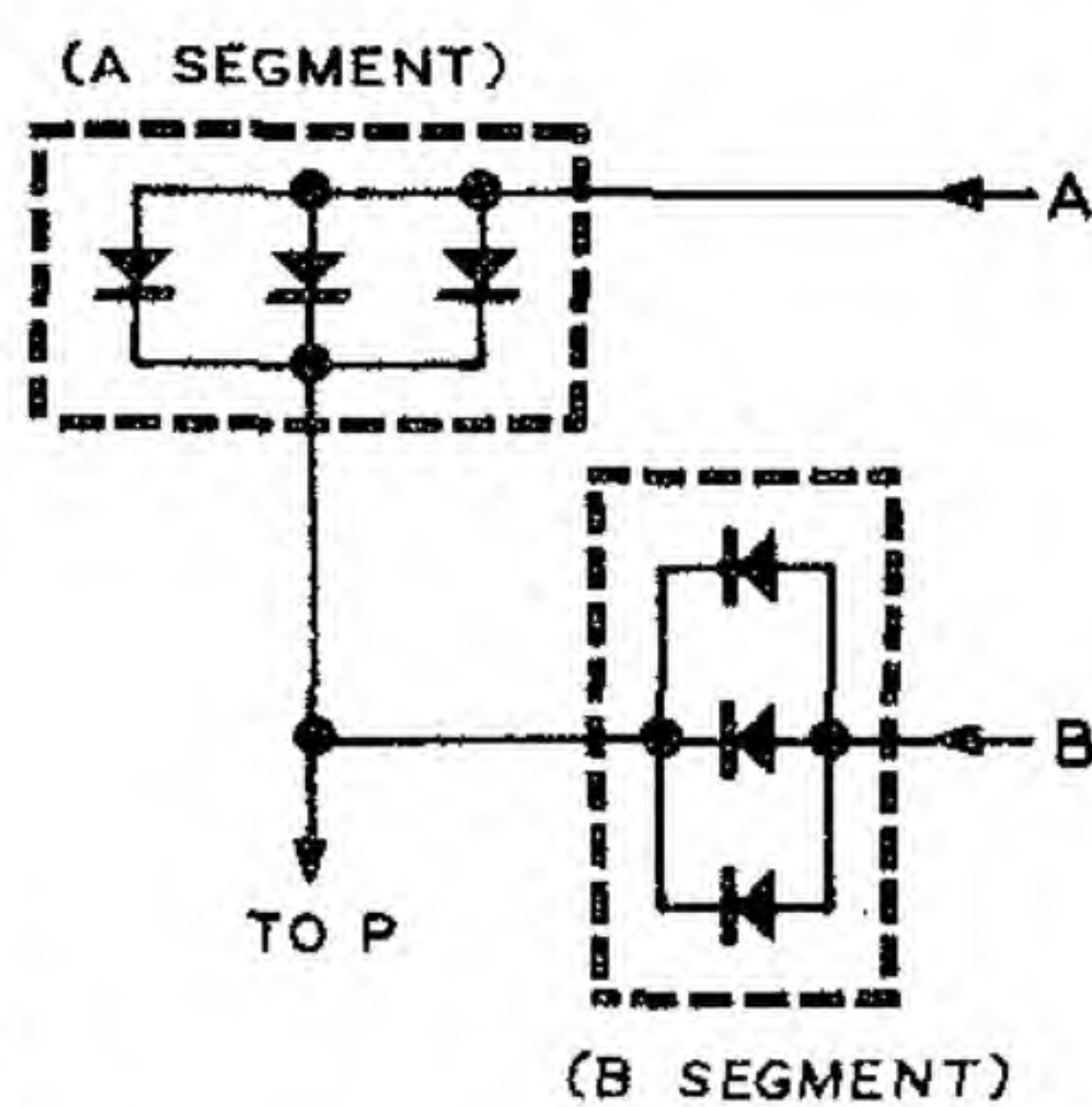


Figure 4-2A

PLAY CIRCUIT

LED (Light Emitting Diode) display is driven by IC2, IC3, IC4, and IC5. These receive control signals from IC1. These control signals form numbers on display by the method illustrated in Figures 4-2A and 4-2B.

Segments (A, B, C, D, E, F, G, and DP) of each digit position are composed of small junction diodes which emit light when current flows through them. All diodes of all segments have one end (the cathode) connected to P of digit. The other end (the anode) of all diodes in the A segment are connected to A. Likewise, all the anodes of the diodes in the B segment are connected to B. This is shown in Figure 4-2A. Current flowing from A to P will "light" the A segment.

Figure 4-2B, the method of forming a "3" is illustrated. Current flowing from C, D, and G to P causes the A, B, C, D, and G segments to light. Since segments E and F are not energized, they do not light.

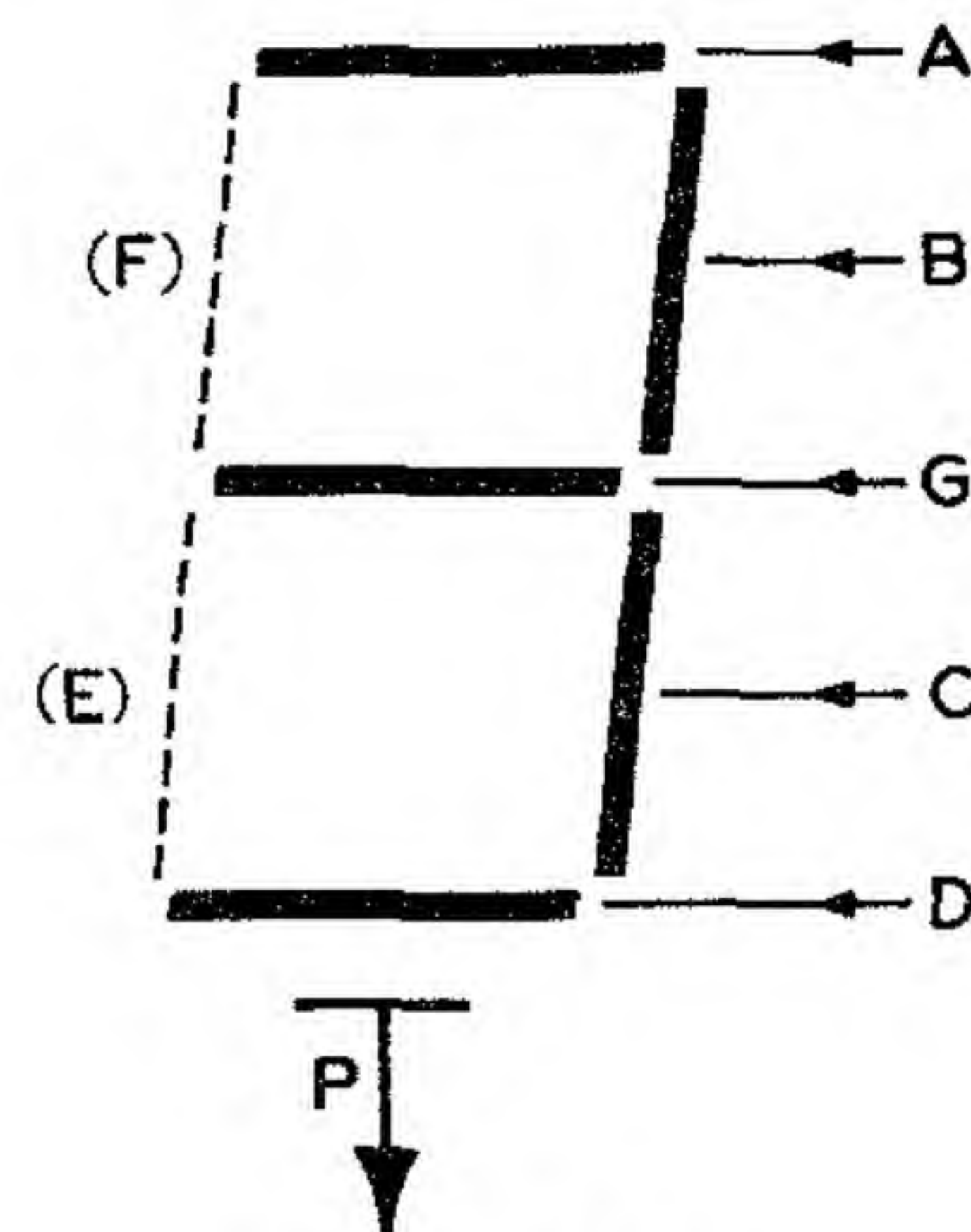


Figure 4-2B

Figure 4-3 shows the driving circuits required to light the numeral 3 in the last digit section (extreme right-hand position) of the LED.

To form the lighted numeral 3, IC1 supplies a turn-on signal through its SA, SB, SC, SD, and SG outputs. (Notice that these outputs are labeled to stand for Segment A, Segment B, etc.) These signals cause IC4 and IC5 to connect the required voltage to be applied to the anodes of segments A, B, C, D, and G of all eight digits of the LED. At the same time, IC1 supplies a turn-on signal through its D1 output to IC2. IC2 connects P1 (the cathode of all the segment diodes in the last digit) to ground creating a current path. This lights the segments to display the numeral 3 at the last (right-hand) digit position.

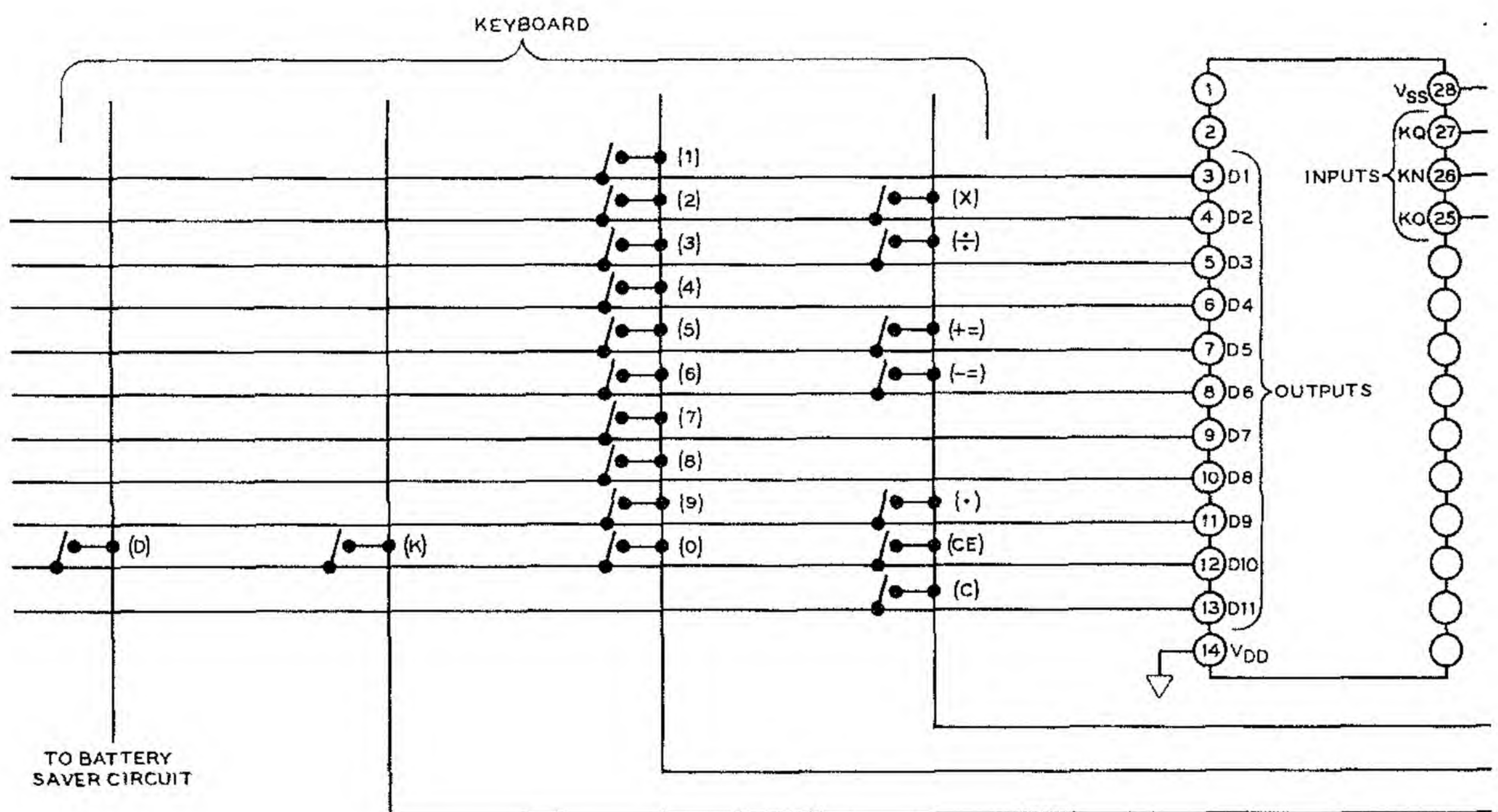


Figure 4-1

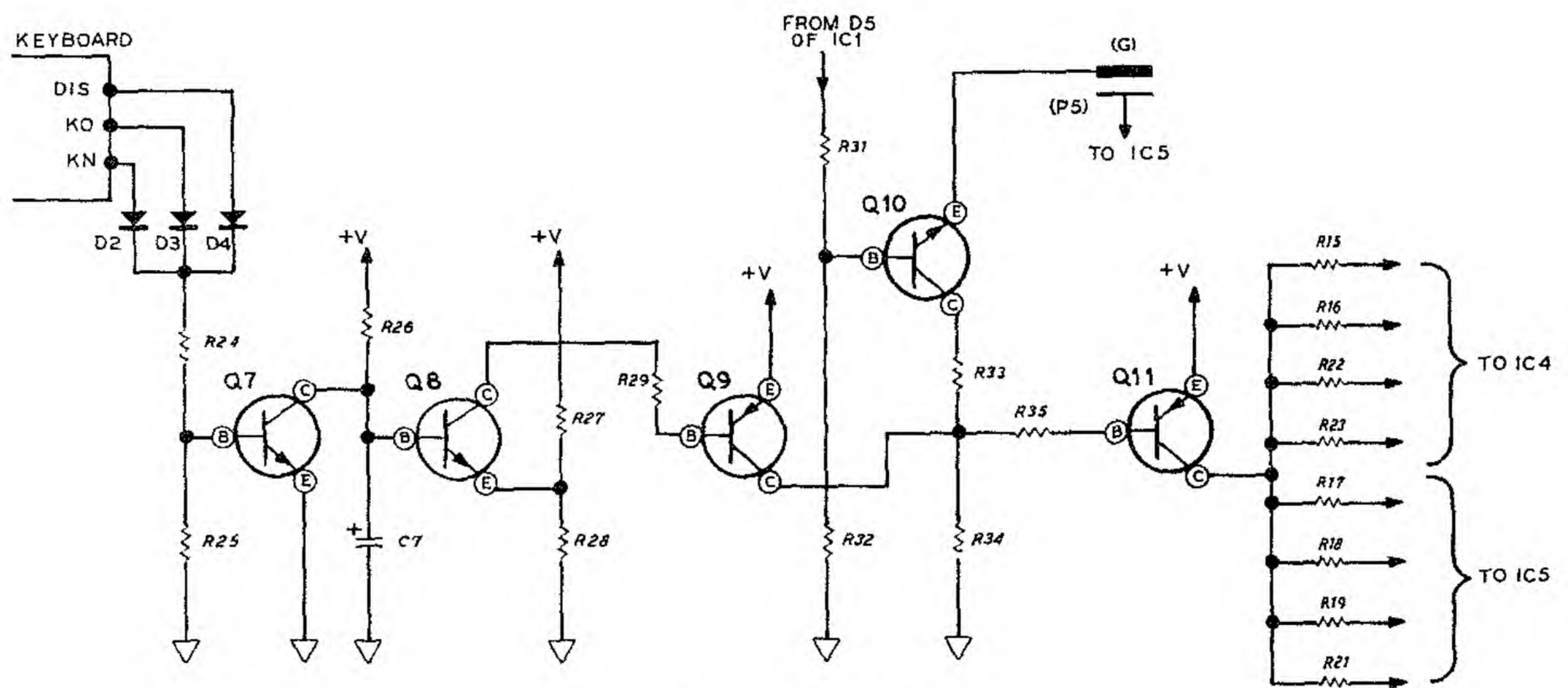
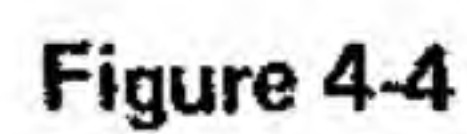


Figure 4-6

Figure 4-8



The pulsating of the internal circuits of IC1 is caused by the signal to the Φ (clock) input. This signal comes from transistor circuits Q1 through Q3 as shown in Figure 4-4.

PLUS-TO-MINUS VOLTAGE CONVERTER

A signal from Q3 (1/2 the multivibrator) is used to turn transistor Q4 off and on. With Q4 turned on, Q5 is turned on and Q6 is turned off by a signal coupled through C4. Under these conditions a current path is developed through Q5, C5, and D6 which causes capacitor C5 to charge. When Q3 turns Q4 and Q5 off, Q6 is turned on. The positive end of C5 is then connected to ground through Q6 and forces the other end of C5 to go negative. This reverse biases D6 and forward biases D5, and applies the negative voltage to C6 which acts as a filter. This on-off change in Q3 (and Q4) causes an accumulated charge at C6 which becomes the negative source voltage. Capacitor C3 acts to minimize radio interference signals.

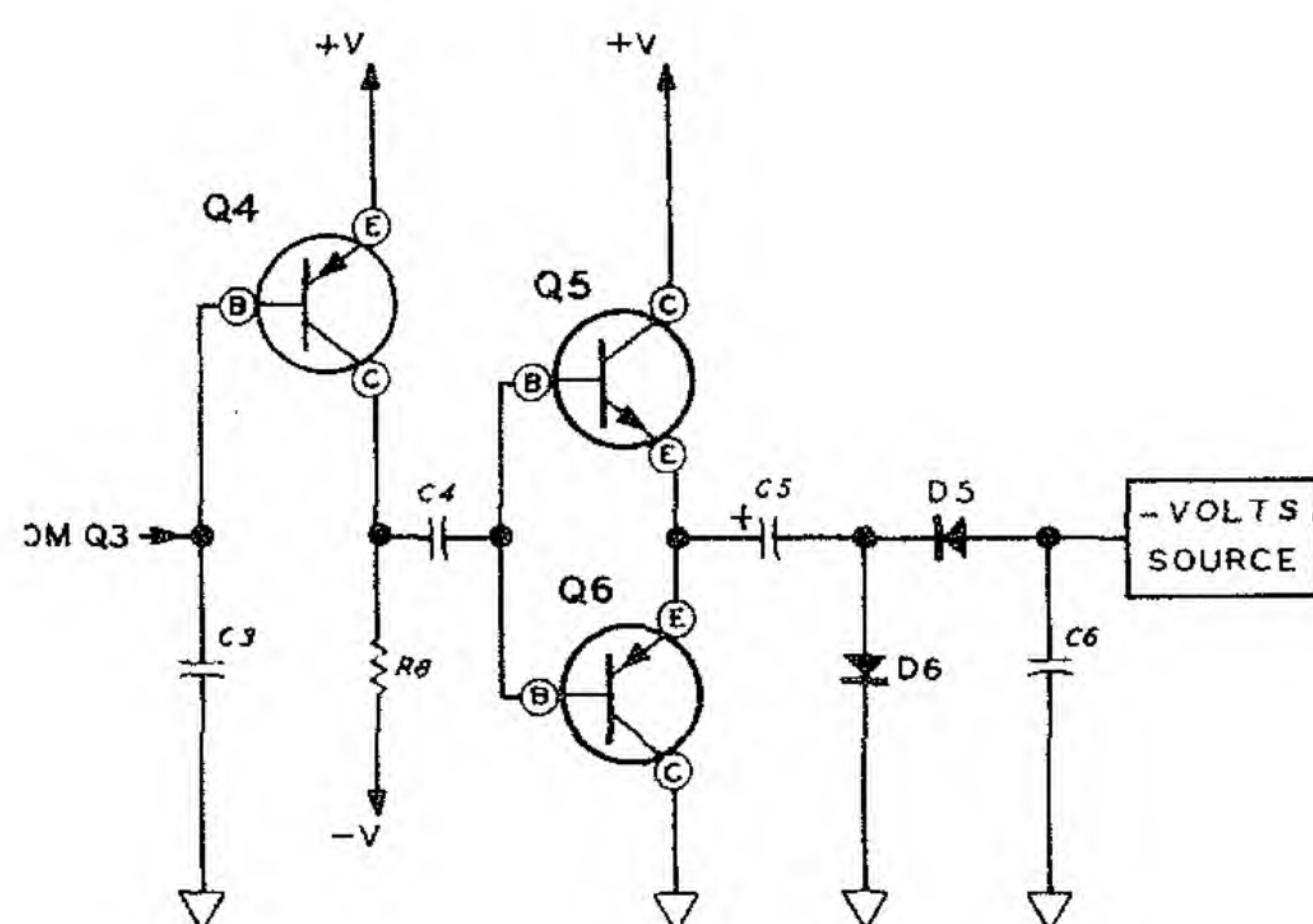


Figure 4-5

BATTERY SAVER CIRCUIT

To conserve battery power and extend operating time, the Display is automatically turned off 15 seconds after the last number or operation entry into the Calculator. This is accomplished by the circuit shown in Figure 4-6 (fold-out from Page 70).

In the "normal mode" of performing a calculation, a voltage is applied through D2, or D3, or D4 and R24 to the base of Q7. This turns Q7 on, which discharges C7. Under this condition, Q8 and Q9 are turned off to remove the positive voltage from the junction of resistors R33, R34, and R35. Current can now flow through R34 and R35 and the emitter-base junction of Q11. This turns on Q11 which then connects the segment driver resistors, R15 through R23, to the positive voltage which permits the segments of the LED to light.

With no entries from the keyboard, Q7 is turned off and C7 begins to charge through R26. When the voltage at the base of Q8 becomes high enough, Q8 and Q9 turn on. The positive voltage from Q9 that is applied to the junction of R33, R34, and R35 turns Q11 off and thus removes the positive voltage from the segment driver resistors, R15 through R23. This action turns off all the lighted segments of the LED. However, the positive voltage from Q9 through R33 turns Q10 on each time D5 of IC1 is pulsed. A positive voltage is now applied to the G segment of the LED and at the same time P5 is grounded by IC3 to light the G segment of the center digit of the LED. Thus indicating that the battery saver circuit is in operation.

Pressing the D key, or any number or operation key, causes Q7 to turn on. This discharges C7 to ground and returns the Calculator to its "normal mode." The D key will make the last display reappear, while pressing any other key will make the LED light but the display may be different depending on the key entry.

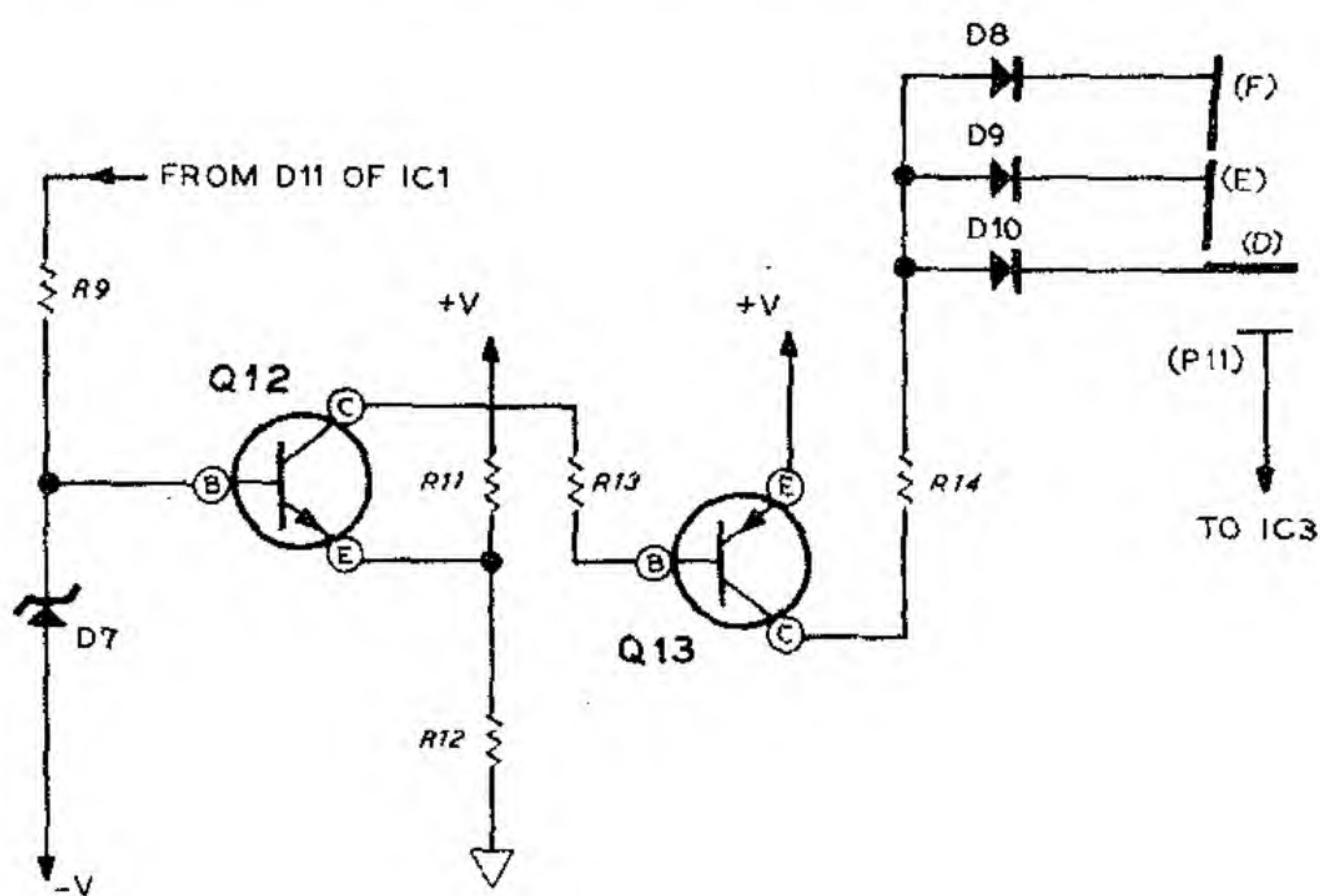


Figure 4-7

LOW VOLTAGE INDICATOR

The circuit which warns that the battery requires charging is shown in Figure 4-7.

Each time D11 of IC1 is pulsed, zener diode D7 is driven into its zener region where the voltage drop across D7 is constant. With this constant voltage drop, and one end of D7 being connected to the negative voltage supply, the base voltage of Q12 must change by the same amount that the negative voltage changes. As the negative voltage drops (approaches zero), the cathode of D7 is forced positive. At some point, the base of Q12 becomes forward biased and turns on Q12 and in turn Q13. With Q13 turned on, a positive voltage is applied through D8, D9, and D10 to the E, F, and D segments of the LED. At the same time P11 of the LED is grounded by IC3 to make an "L" light in the left-most digit of the LED. The value of R12 is selected to match the actual zener voltage of D7 and the value of R11.

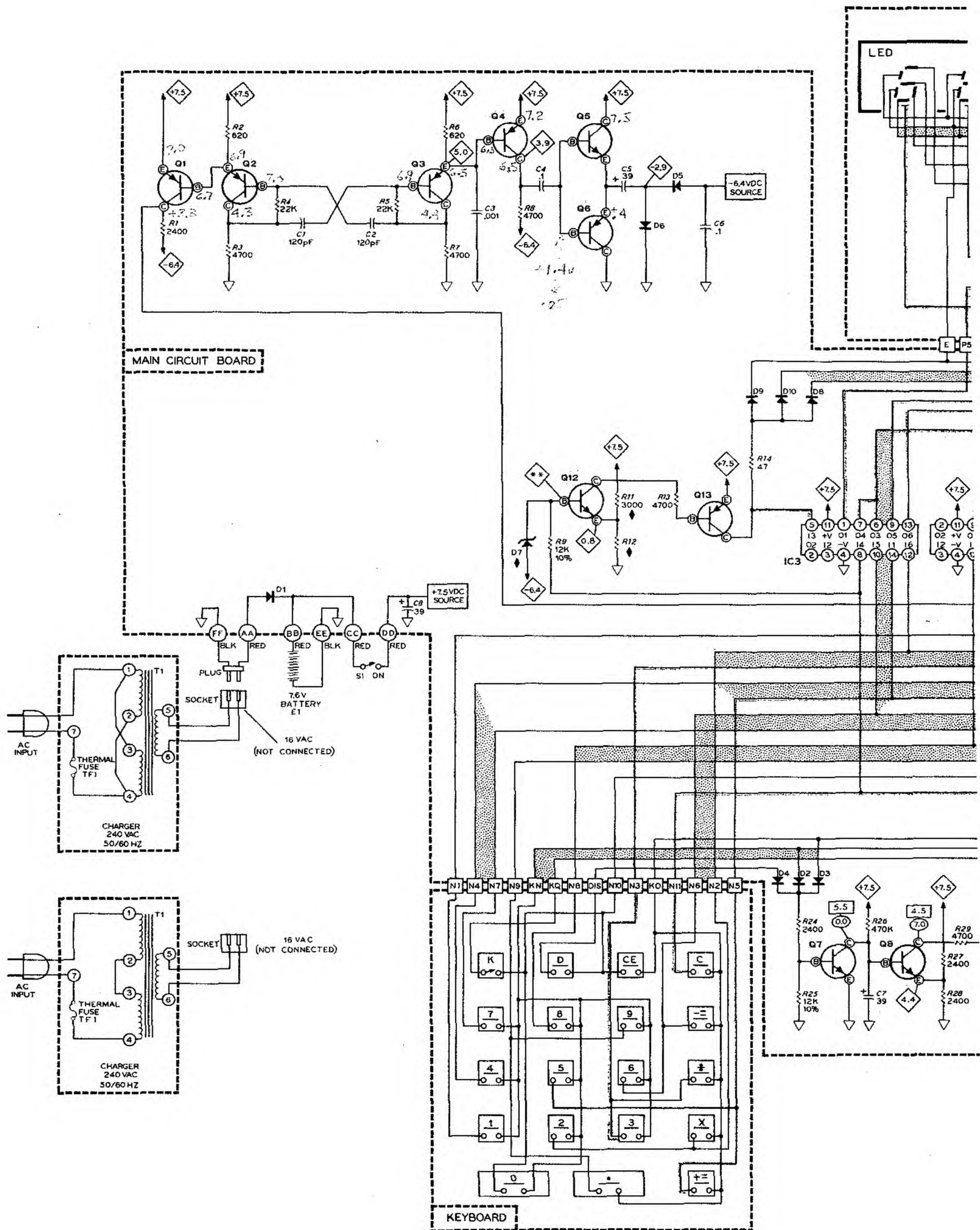
CHARGER AND BATTERY CIRCUIT

The battery and charger circuits are shown in Figure 4-8 (fold-out from Page 70).

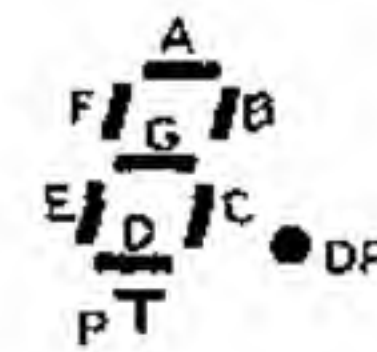
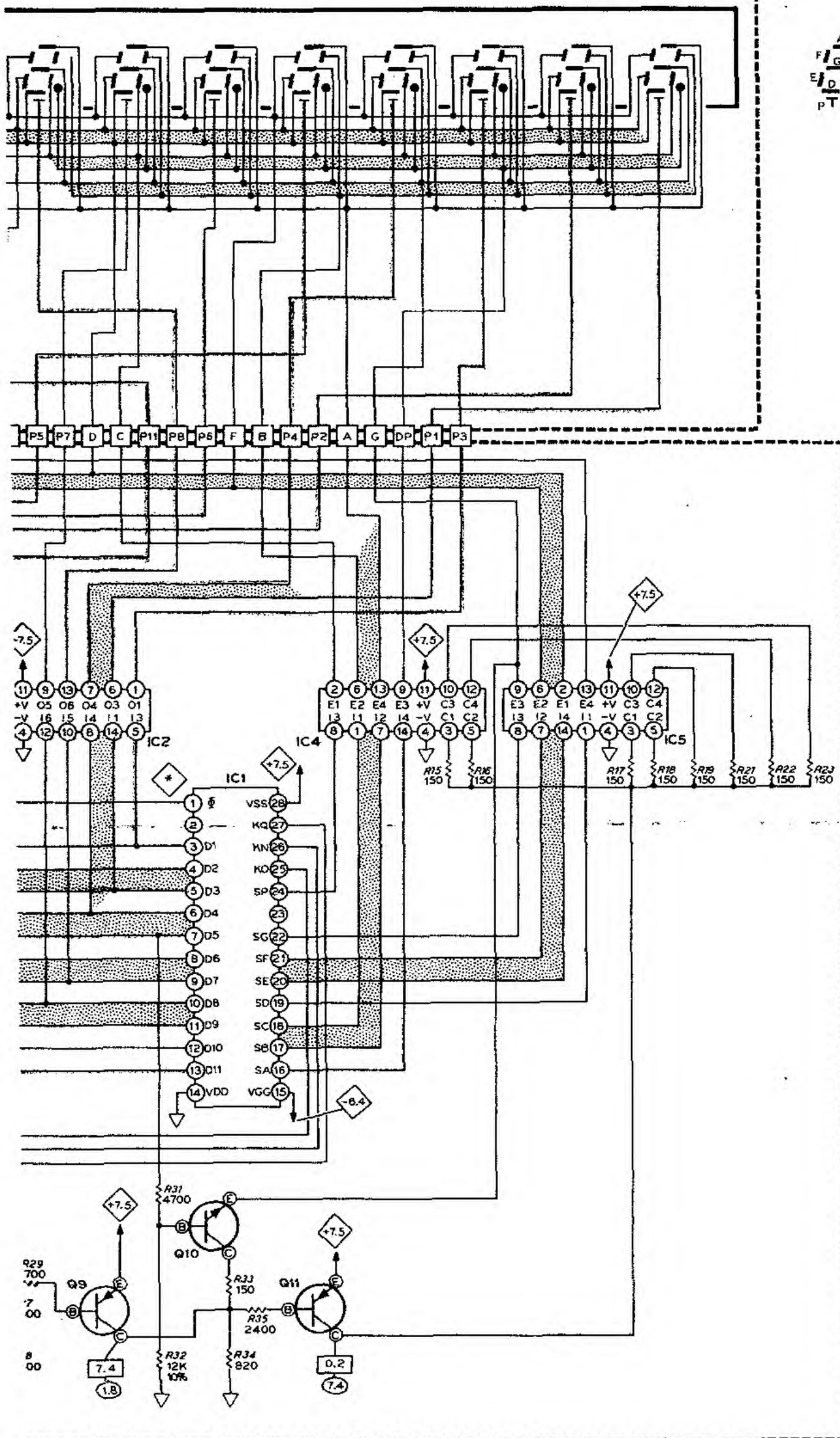
When S1 is closed, the battery (E1) is connected to power the Calculator regardless of whether the Charger is connected or not.

With the Charger connected to the Calculator but not plugged into an AC outlet, D1 is reversed biased to protect the battery from being discharged by transformer T1. When the Charger is connected to the AC line, the stepped-down voltage from the secondary of T1 is applied through D1 to charge the battery.

The secondary of T1 is a special high-resistance winding which limits the current to a safe value. Fuse, F1, protects the transformer from a short circuit on the secondary of T1. Capacitor C8 filters any ripple on the positive voltage source.



DISPLAY CIRCUIT BOARD



SCHEMATIC OF THE HEATHKIT® ELECTRONIC PORTABLE CALCULATOR MODEL IC-2009

NOTES:

1. ALL RESISTORS ARE 1/4 WATT. RESISTOR VALUES ARE IN OHMS (K=1000).
2. ALL RESISTORS ARE 5% UNLESS MARKED OTHERWISE.
3. ALL CAPACITOR VALUES ARE IN μ F UNLESS MARKED OTHERWISE.
4. REFER TO THE CIRCUIT BOARD X-RAY VIEWS AND PHOTOGRAPH FOR THE PHYSICAL LOCATION OF PARTS.
5. ▽ THIS SYMBOL INDICATES A CIRCUIT GROUND.
6. □ THIS SYMBOL INDICATES A CIRCUIT BOARD CONNECTOR PIN AND SOCKET.
7. ○ THIS SYMBOL INDICATES A LETTERED CIRCUIT BOARD CONNECTION.
8. ◆ THIS SYMBOL INDICATES A SELECTED PART FROM THE S Labeled Part #100-1616.
9. SEE THE IDENTIFICATION CHART FOR PROPER IDENTIFICATION OF DIODES, TRANSISTORS, AND INTEGRATED CIRCUITS.
10. NC DENOTES NO CONNECTION.

VOLTAGE MEASUREMENTS

NOTES:

1. BATTERY FULLY CHARGED (MINIMUM 14 HOURS).
2. CHARGER DISCONNECTED.
3. DISPLAY "0".
4. VOLTAGES MEASURED WITH A HIGH IMPEDANCE VOLTMEETER FROM THE POINT INDICATED TO GROUND (SPACER). VOLTAGES MAY VARY $\pm 10\%$.
5. □ DENOTES A VOLTAGE WITH CIRCUIT IN BATTERY SAVER MODE.
6. ○ DENOTES A VOLTAGE WITH THE BATTERY SAVER CIRCUIT OVER-RIDDEN. KEYBOARD REMOVED AND 4700 Ω TEST RESISTOR BETWEEN DIS AND N10 AS SHOWN IN INSET DRAWING (FOLD-OUT FROM PAGE 74).
7. ◆ DENOTES A VOLTAGE WITH THE CIRCUIT IN EITHER NORMAL OR BATTERY SAVER MODE. VOLTAGES MAY BE SLIGHTLY HIGHER IN BATTERY SAVER MODE.
8. ◆* VOLTAGE MAY VARY FROM -2.0 TO 2.0 VOLTS.
9. ◆** VOLTAGE MAY VARY FROM 0.0 TO 0.2 VOLTS.